In: Proceedings of Institute of Electrical and Electronic Engineers, NECEC '90, Newfoundland Electrical and Computer Engineering Conference, "An Electrical Engineering Day". St. John's, NF, May 4, 1990, Poster Session and Notes.
C-CORE Publication No. 90-12.

Beam Forming for Forty Element HF Groundwave Radar Antenna

R.E. Davis P.Eng.
Centre For Cold Ocean Resources Engineering
Memorial University of Newfoundland

Abstract

The narrow receive beam for a high frequency groundwave radar system is synthesized by a combination of coarse steering at the receiver inputs and fine steering at receiver outputs. Coarse steering is implemented in antenna combining and phase shifting hardware while fine steering is implemented in the digital processing of the receiver outputs.

The beamwidth of a linear antenna array is inversely proportional to the aperture of the array. As the aperture of an array is increased by increasing the spacing between elements grating lobes appear in the antenna pattern when the spacing is more than one wavelength. Grating lobes should be avoided because the radar system cannot determine whether a detected target is on the main beam or one of the grating lobes. If the antenna is steered away from broadside a spacing of a half wavelength or less is required to avoid grating lobes. An aperture of twenty wavelengths is required to obtain the desired beamwidth of approximately 3°. Forty receivers would be required if all beam forming is implemented in the digital processing of the receiver outputs.

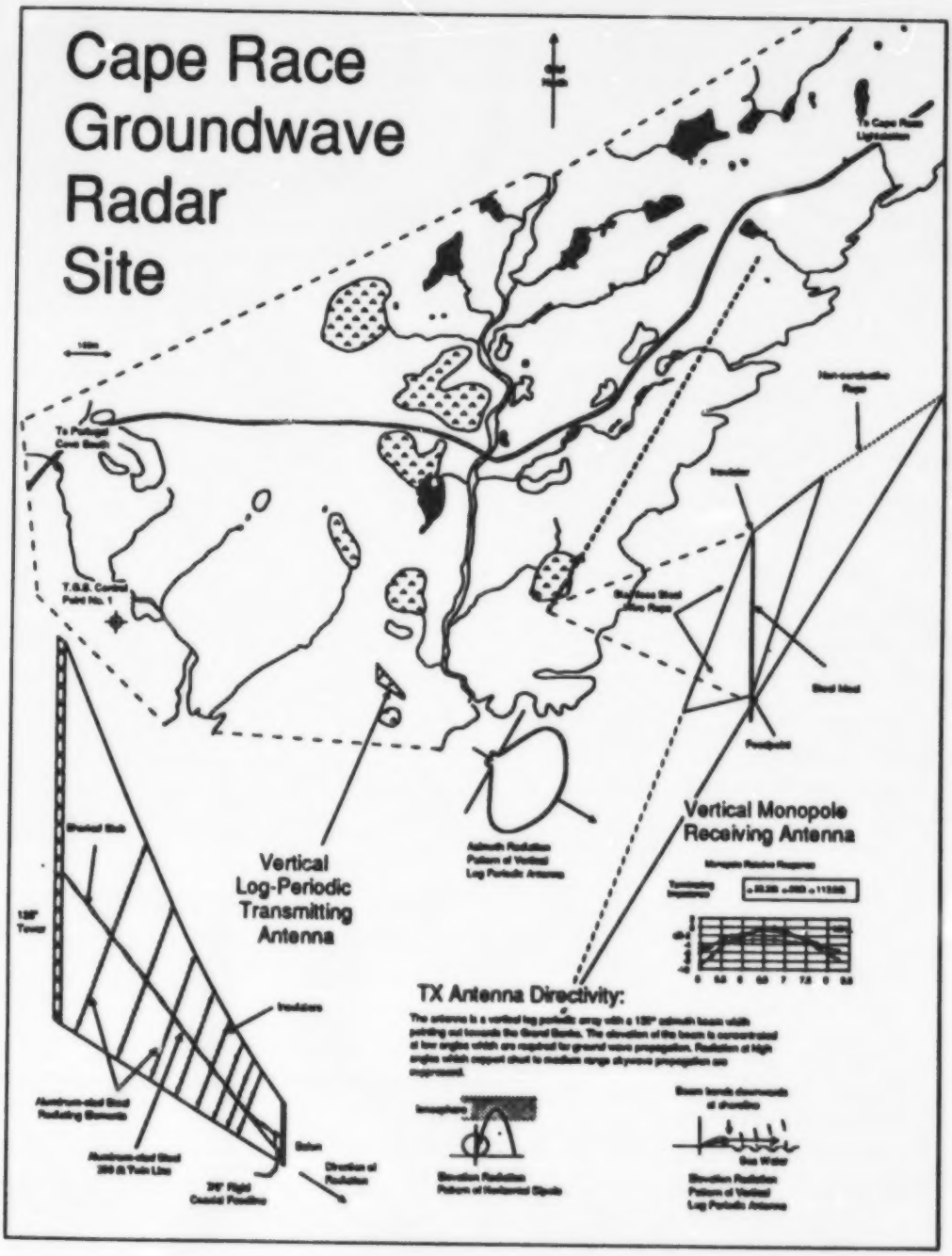
HF radar receivers must have an extremely wide dynamic range in order to extract weak target returns in the presence of very strong clutter. Suitable receivers and the computer hardware to process the large volumes of output data are very expensive. The most effective way to reduce the total cost of an HF groundwave radar system is to reduce the number of receivers, however, the antenna beamwidth must not be increased if the system is to retain its usefulness.

By combining four antennas in a λ/2 spaced sub-array to feed each of ten receivers the desired narrow beamwidth of 3.2° is obtained without grating lobes. The pattern of the four element sub-array is superimposed on the pattern of the ten element 2λ spaced array. The grating lobes of the ten element array are suppressed by nulls of the four element sub-array. Side lobe levels are less than -26 dB when the hardware and software steering are in the same direction.

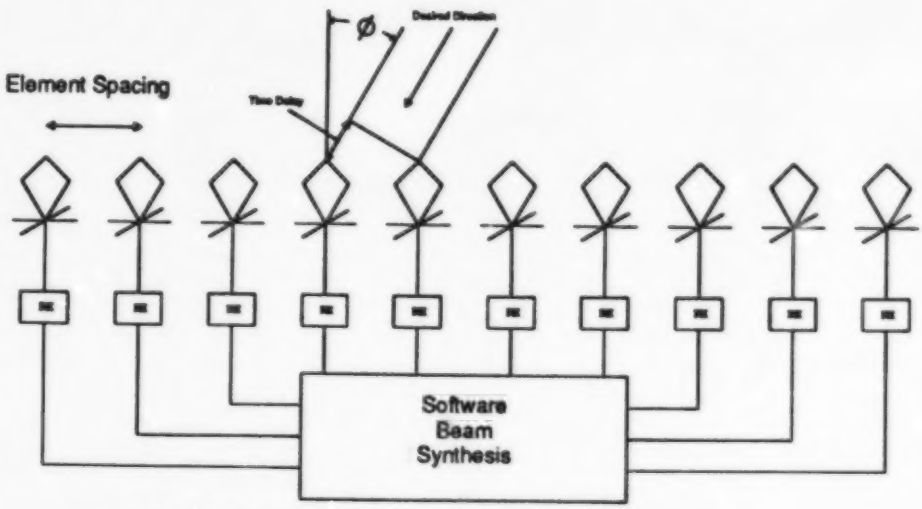
The four element sub-array is steered by hardware which switches fixed delay lines in and out of the signal paths of the combiner. Thirty-one discrete steering headings are available to cover ±90° from broadside with an average step size of 6°. Fine beam headings between these discrete steps are synthesized in digital signal processing of the ten receiver outputs. As the fine beam is steered away from the center of the heading of the four element sub-array the sidelobe levels of the synthesized forty element array pattern increase. With a hardware steering step size of approxomately 6° and a beamwidth of 3.2° it is possible to steer the forty element array in any direction ±90° from broadside with a sidelobe level less than -19 dB. The difference between the fine and coarse steering direction need never be greater than 2°.

Notes on production of posters:

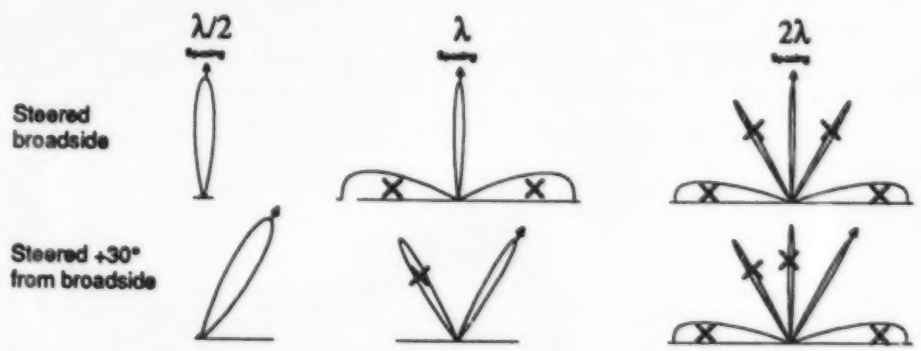
The antenna patterns were produced with Mathematica™ and exported to *Power*Draw™ 3.0 as Adobe Illustrator™ 1.1 files (editable Postscript). A macro instruction in *Power*Draw™ 3.0 was used to read the Illustrator™ 1.1 files into an Engineering C size *Power*Draw™ 3.0 document which was plotted with an HP DraftPro™ plotter on 18" by 24" sheet for display. A special template document was created in *Power*Draw™ 3.0 for use as stationery for the posters. It contains a 402mm by 525mm box on one layer which is prepositioned to plot in the center of the 18" by 24" sheet. Posters are prepared by placing graphics and text inside the boundaries of the box. Posters may be previewed with a LaserWriter™ by printing with 50% reduction specified in the Page Setup menu. The preview poster is centered on a single 8.5" by 11" sheet and only a small band around the bottom and sides of the poster is not shown. For publication in the proceedings each poster was manually repositioned in *Power*Draw™ and printed on a LaserWriter™ at 37% reduction to show the entire poster with the template box and allow a 1.5" left margin for binding and at least 1" on the other sides.


Cape Race
Groundwave
Radar
Site
Vertical
Log-Periodic
Transmitting
Antenna
Vertical Monopole
Receiving Antenna
TX Antenna Directivity:

Beam Synthesis



Digitized data from each receiver is time delayed and combined to obtain a narrow beam in the desired direction.



13° Beamwidth
No Grating Lobes

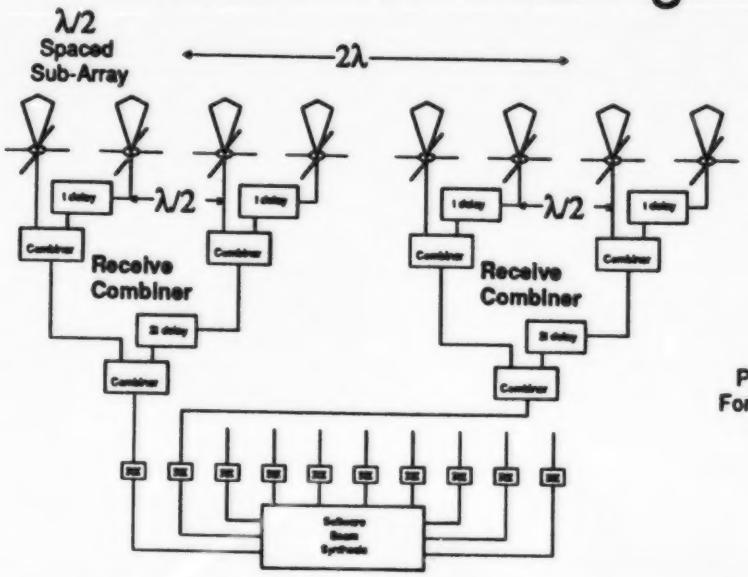
6.5° Beamwidth
Grating Lobes

3.2° Beamwidth
More Grating Lobes

Main Lobe in desired direction

Grating Lobe in undesired direction

Coarse Pre-steering



The receivers have an effective spacing of two wavelengths, the spacing between the sub-arrays.

Pattern of
Four Element
Half Wavelength Spaced
Sub-array

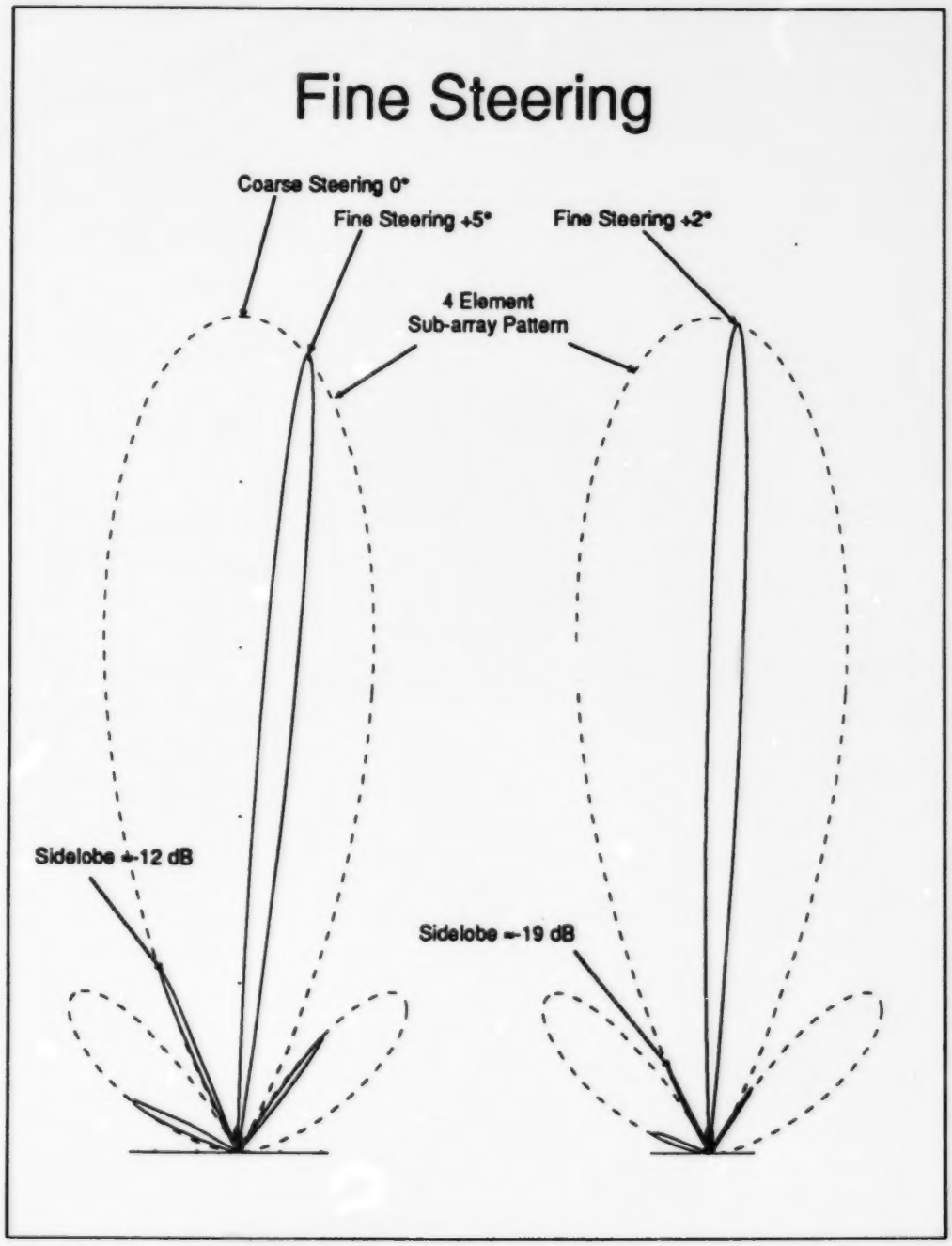
No time delays-
Coarse Steering
in broadside direction

Pattern of
Ten Element
Two Wavelength Spaced
Array

Pattern of
Forty Element
Array

The resulting pattern is: →

There are no grating lobes and the beamwidth is 3.2°.
The sidelobes are 26 dB down.


Fine Steering
Coarse Steering 0°
Fine Steering +5°
Fine Steering +2°
4 Element
Sub-array Pattern
Sidelobe -12 dB
Sidelobe -19 dB